AQUATIC COCKROACHES.

By R. Shelford, M.A., F.L.S.

In 1897 the writer was collecting insects on a mountain close to Kuching, the capital town of the State of Sarawak, in Borneo, and, whilst examining a small pool at the base of a waterfall for water-beetles, discovered several Cockroaches lurking in the sodden leaves scattered about the edge of the pool. The insects, when disturbed, took to the water, and dived to the bottom, where they hid under sticks and stones. The habit was sufficiently remarkable and unexpected to deserve further investigation, and several specimens were captured alive, and placed in a glass tank with some water and an abundance of vegetable *débris*. All the specimens were immature, and of varying size, ranging from 10 millim. to 25 millim. in length. It was observed that they could not endure total immersion in water for any length of time; if a specimen was confined in a tube full of water, and denied all access to air, it would struggle violently for a few minutes in its efforts to escape, and then sink to the bottom of the tube, and there expire. This is what one might expect from the results of certain experiments conducted by Prof. Plateau, of Ghent, on the relative staying powers of land- and water-insects when totally submerged in water. The distinguished Belgian entomologist found that, whilst terrestrial insects will support an immersion for a period ranging from 97½ hours to 22¼ hours, aquatic beetles succumb in periods ranging from 65½ hours to 3 hours. The aquatic Cockroach drowns even more rapidly than aquatic beetles, and it was found that a terrestrial Cockroach, though enduring total immersion for a few hours, is unable to remain alive without air for even the minimum time recorded for terrestrial beetles.

The aquatic Cockroaches that were kept under observation were very inactive, resting for hours at a time on the dead leaves with which they were provided; generally the front part of the body was in the water, but the tip of the abdomen was never submerged, even when all the rest of the body was covered. The abdomen moved up and down with a rhythmic action, and bubbles of air issued at more or less regular intervals from the prothoracic spiracles. These air-bubbles were seen to form gradually, to grow larger and larger, and finally to break away from the spiracles; about twenty per minute passed through the spiracles. Air issued from the mesothoracic spiracles only when the insect was violently agitated. From these observations it seemed fairly obvious that the terminal abdominal spiracles were inspiratory in function, the thoracic spiracles expiratory, and that it was necessary, therefore, for the insect to have the tip of the abdomen exposed to the air, but that it was a matter of indifference whether the expiratory spiracles were above water or below it. In order to settle the question beyond all manner of doubt, some specimens were fastened with cotton threads to strips of cork; half the number were fastened head downwards, the other half head upwards. The cork-strips with the attached insects were then immersed in tubes of water. In the case of the reversed specimens the water covered the thorax and basal segments of the abdomen, but the tip of the abdomen projected above the water-level; the other specimens had the abdomen in the water, but the thorax exposed. The results in every case proved the inspiratory and expiratory functions of the abdominal and thoracic spiracles respectively. The reversed specimens endured their constrained position for many hours (twenty-four to forty-eight or more), and when released seemed little the worse for their experience. On the other hand, the specimens with the abdomen immersed in water died in less than twelve hours, sometimes in less than six. The structure of the thoracic spiracles in Cockroaches is quite different from that of the abdominal spiracles,* and a difference in function is only to be expected; nevertheless, when repeating these experiments with terrestrial Cockroaches, such as *Panesthia javanica*, I was unable to demonstrate satisfactorily the functional differences of their spiracles. This failure may be accounted for—in part, at any rate—by the fact that this species struggled long and violently when pinioned to the cork-strips, and, as they are extremely muscular insects,

* Miall and Denny, 'The Cockroach,' 1886, pp. 151–155, ff. 85–88.

their bonds had to be tightly fastened in order to keep them in position; even then the prisoners did not relax their efforts to free themselves, and I believe that they died of exhaustion and of injuries sustained in their struggles rather than from drowning. The aquatic species, on the other hand, remained comparatively quiet; the reversed specimens, being fastened in a position more or less natural to them, and being able to obtain their supply of air in quite a normal and usual manner, were very little dis-

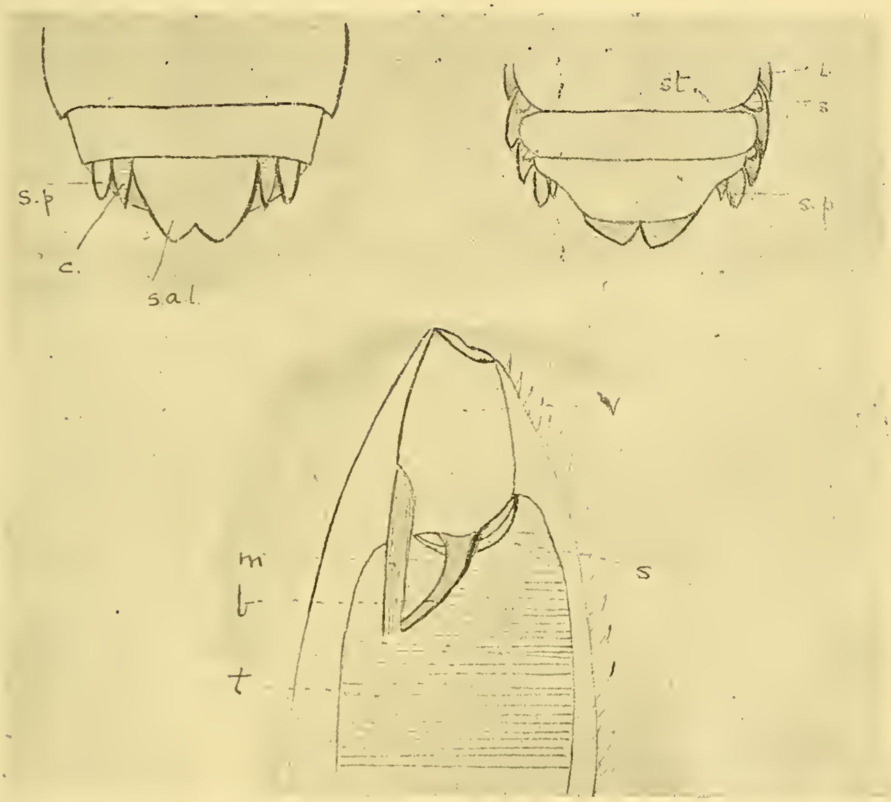

FIG. 1.—End of abdomen of a larva of *Rhicnoda natatrix*, sp. n., dorsal view; *s.p.* spiracular tube; *c.* cercus; *s. a. l.* last dorsal tergite.

FIG. 2.—The same, ventral view; *st.* abdominal sternite; *s.* spiracle; *t.* abdominal tergite.

FIG. 3.—Spiracular tube, highly magnified, seen in optical section; *v.* vestibule; *s.* spiracle; *m.* muscle working *b.*, the chitinous bow; *t.* trachea.

tressed by their bonds, and the other specimens were soon reduced to a comatose condition by the difficulty of obtaining air. The terminal spiracles of these aquatic Cockroaches are situated at the base of two tubes visible on the dorsal side projecting from below the seventh tergite, and external to the anal cerci (fig. 1).

This same feature may be observed in many terrestrial *Blattidæ*, so that it cannot be regarded as associated with the aquatic habit. A microscopic examination of one of these spiracular tubes reveals the following features (fig. 3). The orifice of the tube leads into a short vestibule (*v.*), the vestibule joins a large trachea (*t.*), but intervening between vestibule and trachea is the spiracle (*s.*), a narrow slit in a diaphragm; the slit is opened and closed by the action of a chitinous bow (*b.*), worked by a muscle (*m.*) attached to the wall of the vestibule. This is essentially the structure of all the abdominal spiracles in Cockroaches, and the terminal spiracular tubes of the aquatic species are merely enlarged equivalents, shifted dorsally, of the short spiracular plates of the preceding segments (fig. 2, *s.*), which are situated on the *ventral* side of the abdomen.

Externally, at any rate, the aquatic Cockroaches exhibit no particular modifications for their remarkable habit of life, the legs are not different from those of allied terrestrial genera, and there is nothing in their general appearance to suggest their aquatic habit of life. During the experiments that have been described one distinctive feature, however, in the economy of the insects was notable, *viz.* the ease with which they could remain below the surface of the water. Most adult aquatic insects, e. g. *Dytiscus*, *Corixa*, *Notonecta*, can only keep below the surface by continuing to swim, or by propping themselves under some stone or submerged leaf; directly they relax their efforts they float to the surface. Again, if a large heavy Cockroach, such as *Panesthia javanica*, is thrown into water, it flounders helplessly on the surface, and is quite unable to sink; whereas the much lighter aquatic Cockroach is able to swim, to dive, and to remain submerged with great ease. An explanation of these facts is found if the tracheal systems of the insects are examined. The tracheæ of *Dytiscus* and of *Panesthia* present the usual appearance of opaque silvery tubes filled with air; the tracheæ of the aquatic Cockroaches, on the other hand, are transparent, flattened, strap-like structures, dilated here and there only with air-bubbles. *Dytiscus* and *Panesthia* are buoyed up in water by the plentiful supply of air stored in their bodies, but the tracheæ of the water Cockroach are mere air-passages, not storehouses, the respiratory movements are rapid, causing a constant circulation of air, and if the supply is entirely cut off there is practically no reserve supply contained in the body to draw upon. Hence the rapid death of the insect when totally submerged; if only partially submerged death supervenes less rapidly, probably because some air can be drawn through the thoracic spiracles. *Panesthia javanica* is able to endure *total* immersion longer than the *partial* immersion to which individuals were submitted, because these individuals, when bound, struggled so violently as to make heavy demands on their reserve air-supply; their position was so constrained, so unusual, and so unnatural that they were not able to "take matters quietly," even when fastened in a position presumably favourable to drawing in a fresh supply. Plateau has shown that aquatic insects drown more quickly than terrestrial insects, and suggests that this is because their supply of oxygen is quickly converted into CO_2 through their violent struggles to escape, whereas terrestrial insects, when submerged in water, soon cease to struggle, and, although they become comatose, they recover power of movement when restored to land. It would be of interest to learn if an aquatic insect such as *Dytiscus* would endure partial immersion, *i. e.* with the tip of the abdomen exposed, as well as the aquatic Blattids.

Dr. Nelson Annandale discovered some aquatic Cockroaches in the Malay Peninsula*; the females were wingless, and rested on floating logs, whence they dived into the water when disturbed; the males were winged, and were seen to rise from the surface of the water, but were never seen to enter it. Dr. Annandale states, moreover, that the egg-cases of this species were found in crevices of the floating logs. If the Malay Peninsula species belongs to the same subfamily of *Blattidæ* as the Bornean species, namely, to the *Epilamprinæ*, this discovery of egg-cases is of some interest, for the *Epilamprinæ* are, so far as is known, viviparous insects, the chitinous ootheca deposited by the females of other subfamilies being represented by a delicate membrane enveloping the eggs inside the brood-sac of the mother. Unfortunately, Dr. Annandale's specimens appear to be lost, so that they cannot be identified with certainty.

Another species has been discovered in Formosa,† and Dr.

* Ent. Rec. 1900, p. 76.

† Shiraki, Ann. Zoolog. Japon. vi. 1906, p. 32, pl. 2, f. 4.

Annandale has found an immature specimen in Chota Nagpur, India.* It remains only to give a name to the Bornean species, which appears to be undescribed. The following description is drawn up from an unique female specimen in the Hope Museum, Oxford, evidently the adult of some of the larval forms obtained. The male is unknown.† The Japanese species has been wrongly referred to the genus *Opisthoplatia*; there is no doubt that it is congeneric with the Bornean species.

Subfam. EPILAMPRINÆ.

Genus RHICNODA, Brunner.

Rhicnoda natatrix, sp. n.

♀. Castaneous. Allied to *R. rugosa*, Br., from Burma and Java, but larger, and with the dorsal segments less rugose. Head concavely depressed between the antennal sockets, this area cribrately punctate, rest of head with scattered punctures. Pronotum just covering vertex of head, arcuate, posterior margin truncate, anterior and lateral margins slightly reflected; a few scattered punctures and a pair of impressions on the disc. Tegmina rufous, exceeding the mesonotum in length. Meso- and metanotum and abdominal tergites slightly and irregularly rugose, the posterior margins of the sixth and seventh tergites plicated. Supra-anal lamina produced, apex emarginate, cerci abbreviated, spiracular tubes short; subgenital lamina ample, posterior margin sinuate, disc transversely wrinkled. Front femora with five spines in middle of anterior margin beneath, four spines on posterior margin; formula of apical spines $\frac{2}{1}, \frac{1}{1}, \frac{1}{1}$, front femora with no genicular spine. Posterior metatarsus equals remaining joints. Total length, 35·5 mm.; length of tegmina, 7 mm.; pronotum, 10 mm. × 17·5 mm.

Borneo (Wilson Saunders collection, Hope Museum, Oxford).

* Jour. As. Soc. Bengal (new series), vol. ii. 1906, pp. 105, 106. Dr. Annandale confirms my account of the respiration of these insects, and noted the ease with which his specimen was drowned when totally submerged.

† In a preliminary account of these Cockroaches (Rep. Brit. Assoc. 1901, p. 689) I stated that they consisted of two species—one an Epilamprine, the other a Panesthiine. This is an error due to inaccurate information supplied to me at a time when my knowledge of the *Blattidæ* was less than it is now. All the specimens collected by me are immature, and are referable to two Epilamprine genera, *Rhicnoda* and *Epilampra*. The females of the former genus apparently lead a semi-aquatic life always. I expect that it will be found eventually that some terrestrial species of *Epilampra* are amphibious or aquatic in their earlier stages.